- Methods for predicting the effectiveness of SFRM insulation as a function of its properties, the application characteristics, and the duration and intensity of the fire.
- Methods for predicting service life performance of SFRM under in-service conditions.

Affected Standards: AIA MasterSpec and AWCI Standard 12 for field inspection and conformance criteria; ASTM standards for SFRM performance criteria and test methods. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard. (See Recommendation 10 for more on this issue.)

Recommendation 7. NIST recommends the adoption and use of the "structural frame" approach to fire resistance ratings. This approach requires that structural members—such as girders, beams, trusses and spandrels having direct connection to the columns, and bracing members designed to carry gravity loads—be fire protected to the same fire resistance rating as columns. This approach is currently required by the International Building Code (IBC), one of the model codes, and is in the process of adoption by NFPA 5000, the other model code. This requirement ensures consistency in the fire protection provided to all of the structural elements that contribute to overall structural stability.[33] State and local jurisdictions should adopt and enforce this requirement.

9.2.3 Group 3. New Methods for Fire Resistant Design of Structures

The procedures and practices used in the fire resistant design of structures should be enhanced by requiring an objective that uncontrolled fires result in burnout without partial or global (total) collapse. Performance-based methods are an alternative to prescriptive design methods. This effort should include the development and evaluation of new fire-resistive coating materials and technologies and evaluation of the fire performance of conventional and high-performance structural materials.

Recommendation 8. NIST recommends that the fire resistance of structures be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without partial or global (total) collapse. Such a provision should recognize that sprinklers could be compromised, nonoperational, or nonexistent. Current methods for determining the fire resistance rating of structural assemblies do not explicitly specify a performance objective. The rating resulting from current test methods indicates that the assembly (component or subsystem) continued to support its superimposed load (simulating a maximum load condition) during the test exposure without collapse. *Model Building Codes:* This recommendation should be included into the national model codes as an objective and adopted as an integral part of fire resistance design for structures. The issue of non-operational sprinklers could be addressed using the existing concept of Design Scenario 8 of NFPA 5000, where such compromise is assumed and the result is required to be acceptable to the Authority Having Jurisdiction. *Affected Standards:* ASCE-7, AISC Specifications, ACI 318, and ASCE/SFPE 29.

Recommendation 9. NIST recommends the development of: (1) performance-based standards and code provisions, as an alternative to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse: and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the

[33] Had this requirement been adopted by the 1968 New York City building code, the WTC floor system, including its connections, would have had the 3 hour rating required for the columns since the floors braced the columns.

structure as a whole system. Standards development organizations, including the American Institute of Steel Construction, have already begun developing performance-based provisions to consider the effects of fire in structural design.

This performance-based capability should include the development of, but not be limited to:

a. Standard methodology, supported by performance criteria, analytical design tools, and practical design guidance; related building standards and codes for fire resistance design and retrofit of structures, working through the consensus process for nationwide adoption; comprehensive design rules and guidelines; methodology for evaluating thermostructural performance of structures; and computational models and analysis procedures for use in routine design practice.

b. Standard methodology for specifying multi-compartment, multi-floor fire scenarios for use in the design and analysis of structures to resist fires, accounting for building-specific conditions such as geometry, compartmentation, fuel load (e.g., building contents and any flammable fuels such as oil and gas), fire spread, and ventilation; and methodology for rating the fire resistance of structural systems and barriers under realistic design-basis fire scenarios.

c. Publicly available computational software to predict the effects of fires in buildings—developed, validated, and maintained through a national effort—for use in the design of fire protection systems and the analysis of building response to fires. Improvements should include the fire behavior and contribution of real combustibles; the performance of openings, including door openings and window breakage, that controls the amount of oxygen available to support the growth and spread of fires and whether the fire is fuel-controlled or ventilation-controlled; the floor-to-floor flame spread; the temperature rise in both insulated and uninsulated structural members and fire barriers; and the structural response of components, subsystems, and the total building system due to the fire.

d. Temperature-dependent thermal and mechanical property data for conventional and innovative construction materials

e. New test methods, together with associated conformance assessment criteria, to support the performance-based methods for fire resistance design and retrofit of structures. The performance objective of burnout without collapse will require the development of standard fire exposures that differ from those currently used.

Affected National and International Standards: ASCE-7, AISC Specifications, ACI 318, and ASCE/SFPE 29 for fire resistance design and retrofit of structures; NFPA, SFPE, ASCE, and ISO TC92 SC4 for building-specific multi-compartment, multi-floor design basis fire scenarios; and ASTM, NFPA, UL, and ISO for new test methods. *Model Building Codes:* The performance standards should be adopted as an alternate method in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 10. NIST recommends the development and evaluation of new fire-resistive coating materials, systems, and technologies with significantly enhanced performance and durability to provide protection following major events. This could include, for example, technologies with improved adhesion, double-layered materials, intumescent coatings, and more energy absorbing SFRMs.[34] Consideration should be given to pre-treatment of structural steel

[34] Other possibilities include encapsulation of SFRM by highly elastic energy absorbing membranes or commodity grade carbon fiber or other wraps. The membrane would remain intact under shock, vibration, and impact but may be compromised in a fire, yet allowing the SFRM to perform its thermal insulation function. The carbon wrap would remain intact under shock, vibration, and impact and, possibly, under fire conditions as well.

members with some type of mill-applied fire protection to minimize the uncertainties associated with field application and in-use damage. If such an approach was feasible, only connections and any fire protection damaged during construction and fit-out would need to be field-treated. *Affected Standards:* Technical barriers, if any, to the introduction of new structural fire resistance materials, systems, and technologies should be identified and eliminated in the AIA MasterSpec, AWCI Standard 12 and ASTM standards for field inspection, conformance criteria, and test methods. *Model Building Codes:* Technical barriers, if any, to the introduction of new structural fire resistance materials, systems, and technologies should be eliminated from the model building codes.

Recommendation 11. NIST recommends that the performance and suitability of advanced structural steel, reinforced and pre-stressed concrete, and other high-performance material systems be evaluated for use under conditions expected in building fires. This evaluation should consider both presently available and new types of steels, concrete, and high-performance materials to establish the properties (e.g., yield and ultimate strength, modulus, creep behavior, failure) that are important for fire resistance, establish needed test protocols and acceptance criteria for such materials and systems, compare the performance of newer systems to conventional systems, and the cost-effectiveness of alternate approaches. Technical and standards barriers to the introduction and use of such advanced steel, concrete, and other high-performance material systems should be identified and eliminated, or at least minimized, if they are found to exist. *Affected Standards:* AISC Specifications and ACI 318. Technical barriers, if any, to the introduction of these advanced systems should be eliminated in ASTM E 119, NFPA 251, UL 263, ISO 834. *Model Building Codes:* Technical barriers, if any, to the introduction of these advanced systems should be eliminated from the model building codes.

9.2.4 Group 4. Improved Active Fire Protection

Active fire protection systems (i.e., sprinklers, standpipes/hoses, fire alarms, and smoke management systems) should be enhanced through improvements to design, performance, reliability, and redundancy of such systems.

Recommendation 12. NIST recommends that the performance and possibly the redundancy of active fire protection systems (sprinklers, standpipes/hoses, fire alarms, and smoke management systems) in buildings be enhanced to accommodate the greater risks associated with increasing building height and population, increased use of open spaces, high-risk building activities, fire department response limits, transient fuel loads, and higher threat profile. The performance attributes should deal realistically with the system design basis, reliability of automatic/manual operations, redundancy, and reduction of vulnerabilities due to single point failures. *Affected Standards:* NFPA 13, NFPA 14, NFPA 20, NFPA 72, NFPA 90A, NFPA 92A, NFPA 92B, and NFPA 101. *Model Building Codes:* The performance standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 13. NIST recommends that fire alarm and communications systems in buildings be developed to provide continuous, reliable, and accurate information on the status of life safety conditions at a level of detail sufficient to manage the evacuation process in building fire emergencies; all communication and control paths in buildings need to be designed and installed to have the same resistance to failure and increased survivability above that specified in present standards. This should include means to maintain communications with evacuating occupants that can both reassure them and redirect them if conditions change. Pre-installed fire warden telephone systems in buildings can serve a useful purpose and may be installed in buildings, and if so, they should be made available for use by emergency responders. All

communication and control paths in buildings need to be designed and installed to have the same resistance to failure and increased survivability above that specified in present standards. *Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 14. NIST recommends that control panels at fire/emergency command stations in buildings be adapted to accept and interpret a larger quantity of more reliable information from the active fire protection systems that provide tactical decision aids to fireground commanders, including water flow rates from pressure and flow measurement devices, and that standards for their performance be developed. *Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 15. NIST recommends that systems be developed and implemented for: (1) real-time off-site secure transmission of valuable information from fire alarm and other monitored building systems for use by emergency responders, at any location, to enhance situational awareness and response decisions and maintain safe and efficient operations;[35] and (2) preservation of that information either off-site or in a black box that will survive a fire or other building failure for purposes of subsequent investigations and analysis. Standards for the performance of such systems should be developed, and their use should be required. *Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

9.2.5 Group 5. Improved Building Evacuation

Building evacuation should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness regarding their roles and duties for evacuation during emergencies, and incorporation of appropriate egress technologies.[36]

Recommendation 16. NIST recommends that public agencies, non-profit organizations concerned with building and fire safety, and building owners and managers develop and carry out public education and training campaigns, jointly and on a nationwide scale, to improve building occupants' preparedness for evacuation in case of building emergencies. This effort

---

[35] The alarm systems in the WTC towers were only capable of determining and displaying: (a) areas that had at some time reached alarm point conditions; and (b) areas that had not. The quality and reliability of information available to emergency responders at the Fire Command Station was not sufficient to understand the fire conditions. The only information transmitted outside the building was the fact that the building had gone into alarm. Further, the fire alarm system in WTC 7, which was transmitted to a monitoring service, was on "test" the morning of September 11, 2001, because routine maintenance was being performed. Under test conditions (1) the system is typically disabled for the entire building, not just for the area where work is being performed, and (2) alarm signals typically do not show up on an operator console.

[36] This effort should include standards and guidelines for the development and evaluation of emergency evacuation plans, including best practices for both partial and full evacuation, and the development of contingency plans that account for expected conditions that may require adaptation, including the compromise of all or part of an egress path before or during evacuation, or conditions such as widespread power failure, earthquake, or security threat that restrict egress from the building. Evacuation planning should include the process from initial notification of the need to evacuate to the point the occupants arrive at a place where their safety is ensured. These standards and guidelines should be suitable for assessing the adequacy of evacuation plans submitted for approval and should require occupant training through the conduct of regular drills.

should include better training and self-preparation of occupants, an effectively implemented system of floor wardens and building safety personnel, and needed improvements to standards. Occupant preparedness should include:

a. Improved training and drills for building occupants to ensure that they know evacuation procedures for a variety of emergency scenarios (e.g., including evacuation and shelter in place), are familiar with the egress route, and are sufficiently aware of what is necessary if evacuation is required with minimal notice (e.g., footwear consistent with the distance to be traveled, a flashlight/glow stick for pathway illumination, and dust masks).

b. Building owners and managers should educate tenants on the life safety systems present in their building(s), provide training materials explaining egress routes and stairwell and elevator information, and develop educational programs explaining the most appropriate responses in emergency situations. It is further recommended that the owners and managers of office buildings implement the necessary systems for collecting and storing the training history of each building occupant.

c. Improved training and drills that routinely inform building occupants that roof rescue is not (or is) presently feasible as a standard evacuation option, that they should evacuate down the stairs in any full-building evacuation unless explicitly instructed otherwise by on-site incident commanders, and that elevators can be used if they are still in service and haven't been recalled or stopped.

d. Improved codes, laws, and regulations that do not restrict or impede building occupants during evacuation drills from familiarizing themselves with the detailed layout of alternate egress routes for a full building evacuation.[37]

Affected Standard: ICC/ANSI A117-1. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard. *Affected Organizations:* NFPA, NIBS, NCSBCS, BOMA, and CTBUH.

<u>Recommendation 17.</u> NIST recommends that tall buildings be designed to accommodate timely full building evacuation of occupants when required in building-specific or large-scale emergencies such as widespread power outages, major earthquakes, tornadoes, hurricanes without sufficient advanced warning, fires, explosions, and terrorist attack. Building size, population, function, and iconic status should be taken into account in designing the egress system. Stairwell capacity and stair discharge door width[38] should be adequate to accommodate counterflow due to emergency access by responders.

a. Improved egress analysis models, design methodology, and supporting data should be developed to achieve a target evacuation performance (e.g., time for full building evacuation[39]) for the design building population by considering the building and egress system designs and human factors such as occupant size, mobility status, stairwell tenability conditions, visibility, and congestion.

[37] New York City Local Law 5 prohibits *requiring* occupants to practice stairwell evacuation during drills.

[38] Egress capacity should be based on an all-hazards approach that considers the number and width of stairs (and doors) as well as the possible use of scissor stairs credited as a single stair.

[39] Use of egress models is required to estimate the egress capacity for a range of different evacuation strategies, including full building evacuation. NIST found that the average surviving occupant in the WTC towers descended stairwells at about half the slowest speed previously measured for non-emergency evacuations.

b. To the degree possible, mobility-impaired occupants should be provided a means for self-evacuation in the event of a building emergency. Current strategies (and law) generally require the mobility impaired to shelter-in-place and await assistance. New procedures, which provide redundancy in the event that the floor warden system or co-worker assistance fails, should consider full building evacuation, and may include use of fire-protected and structurally hardened elevators,[40] motorized evacuation technology, and/or dedicated communication technologies for the mobility impaired.

c. If protected/hardened elevators are provided for emergency responders but become unusable during an emergency, due to a malfunction or a conventional threat whose magnitude exceeds the magnitude considered in design, sufficient stairwell capacity should be provided to ensure timely emergency responder access to buildings that are undergoing full evacuation. Such capacity could be provided either via dedicated stairways for fire service use or by building sufficient stairway capacity (i.e., number and width of stairways and/or use of scissor stairs credited as a single stair) to accommodate the evacuation of building occupants while allowing access to emergency responders with minimal hindrance from occupant counterflow.

d. The egress allowance in assembly use spaces should be limited in state and local laws and regulations to no more than a doubling of the stairway capacity for the provision of a horizontal exit on a floor, as is the case now in the national model codes.[41] The use of a horizontal exit creates an area of refuge with a 2 hour fire rated separation, at least one stair on each side, and sufficient space for the expected occupant load.

Affected Standards: NFPA 101, ASME A 17. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 18. NIST recommends that egress systems be designed: (1) to maximize remoteness of egress components (i.e., stairs, elevators, exits) without negatively impacting the average travel distance; (2) to maintain their functional integrity and survivability under foreseeable building-specific or large-scale emergencies; and (3) with consistent layouts, standard signage, and guidance so that systems become intuitive and obvious to building occupants during evacuations.

a. Within a safety-based design hierarchy that should be developed, highest priority should be assigned to maintain the functional integrity, survivability, and remoteness of egress components and active fire protection systems (sprinklers, standpipes, associated water supply, fire alarms, and smoke management systems). The design hierarchy should consider the many systems (e.g., stairs, elevators, active fire protection, mechanical, electrical, plumbing, and structural) and system components, as well as functional integrity, tenant access, emergency responder access, building configuration, security, and structural design.

---

[40] Elevators should be explicitly designed to provide protection against large, but conventional, building fires. *Fire-protected* elevators also should be *structurally hardened* to withstand the range of foreseeable building-specific or large-scale emergencies. While progress has been made in developing the requirements and technologies for fire-protected elevators, similar criteria and designs for structurally hardened elevators remain to be developed.

[41] The New York City Building Code permits a *doubling* of allowed stair capacity when one area of refuge is provided on a floor and a *tripling* of stair capacity for two or more areas of refuge on a floor. In the world of post-September 11, 2001, it is difficult to predict (1) if, and for how long, occupants will be willing to wait in a refuge area before entering an egress stairway, and (2) what the impact would be of such a large group of people moving down the stairs on the orderly evacuation of lower floors.

b. The design, functional integrity, and survivability of the egress and other life safety systems (e.g., stairwell and elevator shafts and active fire protection systems) should be enhanced by considering accidental structural loads such as those induced by overpressures (e.g., gas explosions), impacts, or major hurricanes and earthquakes, in addition to fire separation requirements. In selected buildings, structural loads due to other risks such as those due to terrorism may need to be considered. While NIST does not believe that buildings should be designed for aircraft impact, as the last line of defense for life safety, the stairwells and elevator shafts individually, or the core if these egress components are contained within the core, should have adequate structural integrity to withstand accidental structural loads and anticipated risks.

c. Stairwell remoteness requirements should be met by a physical separation of the stairwells that provide a barrier to both fire and accidental structural loads. Maximizing stairwell remoteness, without negatively impacting the average travel distance, would allow a stairwell to maintain its structural integrity independent of any other stairwell that is subject to accidental loads, even if the stairwells are located within the same structural barrier such as the core. The current "walking path" measurement allows stairwells to be physically next to each other, separated only by a fire barrier. Reducing the clustering of stairways that also contain standpipe water systems provide the fire service with increased options for formulating firefighting strategies. This should not preclude the use of scissor stairs[42] as a means of increasing stair capacity—provided the scissor stair is only credited as a single stair.

d. Egress systems should have consistent layouts with standard signage and guidance so that the systems become intuitive and obvious to all building occupants, including visitors, during evacuations. Particular consideration should be given to unexpected deviations in the stairwells (e.g., floors with transfer hallways).

Affected Standard: NFPA 101. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

<u>Recommendation 19.</u> NIST recommends that building owners, managers, and emergency responders develop a joint plan and take steps to ensure that accurate emergency information is communicated in a timely manner to enhance the situational awareness of building occupants and emergency responders affected by an event. This should be accomplished through better coordination of information among different emergency responder groups, efficient sharing of that information among building occupants and emergency responders, more robust design of emergency public address systems, improved emergency responder communication systems, and use of the Emergency Broadcast System (now known as the Integrated Public Alert and Warning System) and Community Emergency Alert Networks.

a. Situational awareness of building occupants and emergency responders in the form of information and event knowledge should be improved through better coordination of such information among emergency responder groups (9-1-1 dispatch, fire department or police department dispatch, emergency management dispatch, site security, and appropriate federal agencies), efficient sharing and communication of information between building occupants and emergency responders, and improved emergency responder communication systems (i.e., including effective communication within steel and reinforced concrete buildings, capacity commensurate with the scale of operations, and interoperability among different communication systems).

[42] Two separate stairways within the same enclosure and separated by a fire rated partition.

b. The emergency communications systems in buildings should be designed with sufficient robustness and redundancy to continue providing public address announcements or instructions in foreseeable building-specific or large-scale emergencies, including widespread power outage, major earthquakes, tornadoes, hurricanes, fires, and accidental explosions. Consideration should be given to placement of building announcement speakers in stairways in addition to other standard locations.

c. The Integrated Public Alert and Warning System (IPAWS) should be activated and used, especially during large-scale emergencies, as a means to rapidly and widely communicate information to building occupants and emergency responders to enhance their situational awareness and assist with evacuation.

d. Local jurisdictions (cities and counties or boroughs) should seriously consider establishing a Community Emergency Alert Network (CEAN), within the framework of IPAWS, and make it available to the citizens and emergency responders of their jurisdiction to enhance situational awareness in emergencies.[43] The network should deliver important emergency alerts, information and real-time updates to all electronic communications systems or devices registered with the CEAN. These devices may include e-mail accounts, cell phones, text pagers, satellite phones, and wireless PDAs.

Affected Standard: NFPA 101 and/or a new standard. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard to the extent it is within the scope of building and fire codes.

Recommendation 20. NIST recommends that the full range of current and next generation evacuation technologies should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell descent devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access. *Affected Standards:* NFPA 101, ASME A 17, ASTM E 06, ANSI A117.1. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

9.2.6 Group 6. Improved Emergency Response

Technologies and procedures for emergency response should be improved to enable better access to buildings, response operations, emergency communications, and command and control in large-scale emergencies.

Recommendation 21. NIST recommends the installation of fire-protected and structurally hardened elevators to improve emergency response activities in tall buildings by providing timely emergency access to responders and allowing evacuation of mobility-impaired building occupants. Such elevators should be installed for exclusive use by emergency responders during emergencies.[44] In tall buildings, consideration also should be given to installing such elevators for

[43] Types of emergency communications could include life safety information, severe weather warnings, disaster notifications (including information on terrorist attacks), directions for self-protection, locations of nearest available shelters, precautionary evacuation information, identification of available evacuation routes, and accidents or obstructions associated with roadways and utilities.

[44] The access time for emergency responders, in tall building emergencies where elevators are not functioning and only stairways can be used, averages between 1 min and 2 min per floor, which, for example, corresponds to between 1 1/2 hour and 2 hours (depending on the amount of gear and equipment carried) to reach the 60th floor of a tall building. Further, the physiological

use by all occupants. NIST has found that the physiological impacts on emergency responders of climbing numerous (e.g., 20 or more) stories makes it difficult to conduct effective and timely firefighting and rescue operations in building emergencies without functioning elevators. The use of elevators for these purposes will require additional operating procedures and protocols, as well as a requirement for release of elevator door restrictors by emergency response personnel.

Affected Standards: ASME A 17, ANSI 117.1, NFPA 70, NFPA 101, NFPA 1221, NFPA 1500, NFPA 1561, NFPA 1620, and NFPA 1710. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 22. NIST recommends the installation, inspection, and testing of emergency communications systems, radio communications, and associated operating protocols to ensure that the systems and protocols: (1) are effective for large-scale emergencies in buildings with challenging radio frequency propagation environments; and (2) can be used to identify, locate, and track emergency responders within indoor building environments and in the field. The federal government should coordinate its efforts that address this need within the framework provided by the SAFECOM program of the Department of Homeland Security.

a. Rigorous procedures, including pre-emergency inspection and testing, should be developed and implemented for ensuring the operation of emergency communications systems and radio communications in tall buildings and other large structures (including tunnels and subways), or at locations where communications are difficult.

b. Performance requirements should be developed for emergency communications systems and radio communications that are used within buildings or in built-up urban environments, including standards for design, testing, certification, maintenance, and inspection of such systems.

c. An interoperable architecture for emergency communications networks—and associated operating protocols—should be developed for unit operations within and across agencies in large-scale emergencies. The overall network architecture should cover local networking at incident sites, dispatching, and area-wide networks, considering: (a) the scale of needed communications in terms of the number of emergency responders using the system in a large-scale emergency and the organizational hierarchy; (b) challenges associated with radio frequency propagation especially in buildings; (c) interoperability with existing legacy emergency communications systems (i.e., between conventional two-way systems and newer wireless network systems); and (d) the need to identify, locate, and track emergency responders at an incident site.

Affected Standards: FCC, SAFECOM, NFPA Standards on Electronic Safety Equipment, NFPA 70, NFPA 297, and NFPA 1221. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 23. NIST recommends the establishment and implementation of detailed procedures and methods for gathering, processing, and delivering critical information through integration of relevant voice, video, graphical, and written data to enhance the situational awareness of all emergency responders. An information intelligence sector[45] should be established to coordinate the effort for each incident. *Affected Standards:* National Incident

impact on the emergency responders of climbing more than 10 to 12 floors in a tall building makes it difficult for them to immediately begin aggressive firefighting and rescue operations.

[45] A group of individuals that is knowledgeable, experienced, and specifically trained in gathering, processing, and delivering information critical for emergency response operations and is ready for activation in large and/or dangerous events.

Management System (NIMS), NRP, SAFECOM, FCC, NFPA Standards on Electronic Safety Equipment, NFPA 1500, NFPA 1561, NFPA 1620, NFPA 1710, and NFPA 1221. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.

Recommendation 24. NIST recommends the establishment and implementation of codes and protocols for ensuring effective and uninterrupted operation of the command and control system for large-scale building emergencies.

a. State, local, and federal jurisdictions should implement NIMS. The jurisdictions should work with the Department of Homeland Security to review, test, evaluate, and implement an effective unified command and control system. NIMS addresses interagency coordination and establishes a response matrix—assigning lead agency responsibilities for different types of emergencies and functions. At a minimum, each supporting agency should assign an individual to provide coordination with the lead agency at each incident command post.

b. State, local, and federal emergency operations centers (EOCs) should be located, designed, built, and operated with security and operational integrity as a key consideration.

c. Command posts should be established outside the potential collapse footprint of any building which shows evidence of large multi-floor fires or has serious structural damage. A continual assessment of building stability and safety should be made in such emergencies to guide ongoing operations and enhance emergency responder safety. The information necessary to make these assessments should be made available to those assigned responsibility (see related Recommendations 15 and 23).

d. An effective command system should be established and operating before a large number of emergency responders and apparatus are dispatched and deployed. Through training and drills, emergency responders and ambulances should be required to await dispatch requests from the incident command system and not to self-dispatch in large-scale emergencies.

e. Actions should be taken via training and drills to ensure a coordinated and effective emergency response at all levels of the incident command chain by requiring all emergency responders that are given an assignment to immediately adopt and execute the assignment objectives.

f. Command post information and incident operations data should be managed and broadcast to command and control centers at remote locations so that information is secure and accessible by all personnel needing the information. Methods should be developed and implemented so that any information that is available at an interior information center is transmitted to a emergency responder vehicle or command post outside the building.

Affected Standards: NIMS, NRP, SAFECOM, FCC, NFPA Standards on Electronic Safety Equipment, NFPA 1221, NFPA 1500, NFPA 1561, NFPA 1620, and NFPA 1710. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.

9.2.7 Group 7. Improved Procedures and Practices

The procedures and practices used in the design, construction, maintenance, and operation of buildings should be improved to include encouraging code compliance by nongovernmental and quasi-governmental entities, adoption and application of egress and sprinkler requirements in codes for existing buildings, and retention and availability of building documents over the life of a building.

<u>Recommendation 25.</u> Nongovernmental and quasi-governmental entities that own or lease buildings and are not subject to building and fire safety code requirements of any governmental jurisdiction are nevertheless concerned about the safety of the building occupants and the responding emergency personnel. NIST recommends that such entities be encouraged to provide a level of safety that equals or exceeds the level of safety that would be provided by strict compliance with the code requirements of an appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends that as-designed and as-built safety be certified by a qualified third party, independent of the building owner(s). The process should not use self-approval for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the life of the buildings.[46]

<u>Recommendation 26.</u> NIST recommends that state and local jurisdictions adopt and aggressively enforce available provisions in building codes to ensure that egress and sprinkler requirements are met by existing buildings.[47] Further, occupancy requirements should be modified where needed (such as when there are assembly use spaces within an office building) to meet the requirements in model building codes. Provisions related to egress and sprinkler requirements in existing buildings are available in such codes as the *International Existing Building Code (IEBC), International Fire Code,* NFPA 1, NFPA 101, and ASME A 17.3. For example, the IEBC defines three levels of building alteration (removal and replacement or covering of existing materials and equipment, reconfiguration of space or system or installation of new equipment, and work area in excess of 50 percent of the aggregate area of the building). At the lowest level there are no upgrade implications for sprinklers and the egress system. At the next level, sprinklers are required in work areas serving greater than 30 persons if certain other conditions related to building height and use such as shared exists also are met. There are numerous requirements for means of egress, including number of exits, specification of doors, dead-end corridors and travel distances, lighting, signage, and handrails. At the highest level, the sprinkler and egress requirements are identical to the second level without the minimum 30 person restriction and the other conditions related to building height and use. The Life Safety Code (NFPA 101) applies retroactively to all buildings, independent of whether any work is currently being done on the building, and ASME 17.3 applies retroactively to all elevators as a minimum set of requirements.

<u>Recommendation 27.</u> NIST recommends that building codes incorporate a provision that requires building owners to retain documents, including supporting calculations and test data, related to building design, construction, maintenance and modifications over the entire life of

---

[46] The long-standing stated policy of The Port Authority of New York and New Jersey (PANYNJ) was to meet and, where appropriate, exceed the requirements of local building and fire codes, and it entered into agreements with the New York City Department of Buildings and The Fire Department of the City of New York in accordance with that policy. Although the PANYNJ sought review and concurrence from New York City in the areas listed in the recommendation, the PANYNJ was not required to yield, and appears not to have yielded, approval authority to New York City. The PANYNJ was created as an interstate entity, a "body corporate and politic," under its charter, pursuant to Article 1, Section 10 of the U.S. Constitution permitting compacts between states. Further, there are many other similar nongovernmental and quasi-governmental entities in the United States. A comprehensive review of documents conducted as part of this Investigation suggests that the WTC towers generally were designed and maintained consistent with the requirements of the 1968 New York City Building Code. Areas of concern included fireproofing of WTC floor system, height of tenant separation walls, and egress requirements for the assembly use space for the Windows of the World in WTC 1 and Top of the World observation deck in WTC 2. These areas of concern did not play a significant role in determining the outcomes related to the events of September 11, 2001.

[47] The WTC towers were unsprinklered when built. It took nearly 28 years after passage of New York City Local Law 5 in 1973, which required either compartmentation or sprinklering, for the buildings to be fully sprinklered (the Port Authority chose not to use the compartmentation option in Local Law 5). This was about 13 years more than the 15-year period for full compliance with Local Law 5 that was set by Local Law 84 of 1979.

the building.[48] Means should be developed for offsite storage and maintenance of the documents. In addition, NIST recommends that relevant building information be made available in suitably designed hard copy or electronic format for use by emergency responders. Such information should be easily accessible by responders during emergencies. *Model Building Codes:* Model building codes should incorporate this recommendation. State and local jurisdictions should adopt and enforce these requirements.

Recommendation 28. NIST recommends that the role of the "Design Professional in Responsible Charge"[49] be clarified to ensure that: (1) all appropriate design professionals (including, e.g., the fire protection engineer) are part of the design team providing the standard of care when designing buildings employing innovative or unusual fire safety systems,[50] and (2) all appropriate design professionals (including, e.g., the structural engineer and the fire protection engineer) are part of the design team providing the standard of care when designing the structure to resist fires, in buildings that employ innovative or unusual structural and fire safety systems. *Affected Standards:* AIA Practice Guidelines. *Model Building Codes:* The IBC, which already defines the "Design Professional in Responsible Charge," be clarified to address this recommendation. The NFPA 5000 should incorporate the "Design Professional in Responsible Charge" concept and address this recommendation.

9.2.8 Group 8. Education and Training

The professional skills of building and fire safety professionals should be upgraded through a national education and training effort for fire protection engineers, structural engineers, and architects. The skills of the building regulatory and fire service personnel should also be upgraded to provide sufficient understanding and the necessary skills to conduct the review, inspection, and approval tasks for which they are responsible.

Recommendation 29. NIST recommends that continuing education curricula be developed and programs be implemented for (1) training fire protection engineers and architects in structural engineering principles and design, and (2) training structural engineers, architects, fire protection engineers, and code enforcement officials in modern fire protection principles and technologies, including fire-resistance design of structures, and (3) training building regulatory and fire service personnel to upgrade their understanding and skills to conduct the review, inspection, and approval tasks for which they are responsible. The outcome would further the integration of the disciplines in effective fire-safe design of buildings. *Affected Organizations:* AIA, SFPE, ASCE, ASME, AISC, ACI, and state licensing boards. *Model Building Codes:* Detailed criteria and requirements should be incorporated into the model building codes under the topic "Design Professional in Responsible Charge."

---

[48] The availability of inexpensive electronic storage media and tools for creating large searchable databases make this feasible.

[49] In projects involving a design team, the "Design Professional in Responsible Charge"—usually the lead architect—ensures that the team members use consistent design data and assumptions, coordinates overlapping specifications, and serves as the liaison to the enforcement and reviewing officials and to the owner. The term is defined in the International Building Code and in the ICC Performance Code for Buildings and Facilities (where it is the Principal Design Professional).

[50] If the fire safety concepts in tall buildings had been sufficiently mature in the 1960s, it is possible that the risks associated with jet-fuel ignited multi-floor fires might have been recognized and taken into account when the impact of a Boeing 707 aircraft was considered by the structural engineer during the design of the WTC towers.

<u>Recommendation 30.</u> NIST recommends that academic, professional short-course, and web-based training materials in the use of computational fire dynamics and thermostructural analysis tools be developed and delivered to strengthen the base of available technical capabilities and human resources. *Affected Organizations:* AIA, SFPE, ASCE, ASME, AISC, and ACI, ICC, NFPA.

9.3 NEXT STEPS

After issuance of the final report, the National Construction Safety Team Act requires NIST to:

- Conduct, or enable or encourage the conducting of, appropriate research recommended by the Team;
- Promote (consistent with existing procedures for the establishment of building standards, codes, and practices) the appropriate adoption by the Federal Government, and encourage the appropriate adoption by other agencies and organizations, of the recommendations of the Team with respect to—
  - Technical aspects of evacuation and emergency response procedures;
  - Specific improvements to building standards, codes, and practices; and
  - Other actions needed to help present future building failures.

NIST is assigning top priority to work vigorously with the building and fire safety communities to assure that there is a complete understanding of the recommendations and to provide needed technical assistance in getting them implemented. NIST has identified specific codes, standards, and practices affected by each of the recommendations (Tables 9-2a, 9-2b, and 9-2c) and already begun to reach out to the responsible organizations to pave the way for a timely, expedited consideration of the recommendations. Toward this end, NIST held a conference September 13–15, 2005, that was attended by over 200 people, including all of the major standards and codes development organizations.

NIST also has awarded a contract to the National Institute of Building Sciences (NIBS) to convene a panel of building code experts to turn appropriate recommendations into code language suitable for submission of code change proposals to the two national model code developers.

In addition, NIST will implement a web-based system so that the public can track progress on implementing the recommendations. The web site will list each of the recommendations, the specific organization or organizations (e.g., standards and code developers, professional groups, state and local authorities) responsible for its implementation, the status of its implementation by organization, and the plans or work in progress to implement the recommendations.

Table 9–1. Crosswalk of Recommendations to Categories.

Recommendation Area	Recommendation Group	Recommendation Number	Responsible Community: Practices	Responsible Community: Standards, Codes, Regulations	Responsible Community: Adoption & Enforcement	Responsible Community: R&D/Further Study	Responsible Community: Education & Training	Application: All Tall Buildings	Application: Selected Other Buildings	Relation to 9/11 Outcome: Related	Relation to 9/11 Outcome: Unrelated
Increased Structural Integrity	1	1	✓	✓	✓	✓	✓	✓	✓	✓	
		2	✓	✓		✓		✓	✓		✓
		3	✓	✓		✓		✓			✓
Enhanced Fire Endurance of Structures	2	4	✓	✓		✓		✓			✓
		5		✓		✓		✓			✓
		6	✓	✓	✓	✓		✓			✓
		7		✓	✓		✓	✓	✓		✓
New Methods for Fire Resistant Design of Structures	3	8	✓	✓	✓	✓	✓	✓	✓	✓	
		9	✓	✓		✓	✓	✓	✓		✓
		10	✓	✓		✓		✓	✓	✓	
		11	✓			✓		✓	✓		✓
Improved Active Fire Protection	4	12	✓	✓		✓		✓	✓	✓	
		13		✓		✓		✓		✓	
		14		✓		✓		✓	✓	✓	
		15	✓	✓		✓		✓	✓	✓	✓
Improved Building Evacuation	5	16	✓	✓		✓	✓	✓		✓	✓
		17	✓	✓		✓	✓	✓	✓	✓	✓
		18	✓	✓				✓		✓	
		19	✓	✓			✓	✓	✓	✓	
		20	✓	✓		✓		✓	✓	✓	

Recommendation Area	Recommendation Group	Recommendation Number	Responsible Community: Practices	Responsible Community: Standards, Codes, Regulations	Responsible Community: Adoption & Enforcement	Responsible Community: R&D/Further Study	Responsible Community: Education & Training	Application: All Tall Buildings	Application: Selected Other Buildings	Relation to 9/11 Outcome: Related	Relation to 9/11 Outcome: Unrelated
Improved Emergency Response	6	21	✓	✓		✓		✓		✓	
		22	✓	✓	✓	✓	✓	✓		✓	
		23	✓	✓	✓	✓	✓	✓	✓	✓	
		24	✓	✓	✓	✓	✓	✓		✓	
Improved Procedures and Practices	7	25	✓	✓	✓			✓	✓		✓
		26	✓		✓			✓	✓		✓
		27	✓	✓	✓			✓	✓	✓	
		28	✓	✓			✓	✓	✓	✓	
Education and Training	8	29	✓	✓			✓	✓	✓	✓	
		30	✓				✓	✓	✓		✓

Table 9–2a. Standards Affected by the Recommendations.

Affected Standard	Group Number	Recommendation
American Concrete Institute, ACI 318 - Building Code Requirements for Structural Concrete	1. Increased Structural Integrity 3. New Methods for Fire Resistant Design of Structures	1, 3, 8, 9, 11
American Institute of Architects, AIA MASTERSPEC – Master Specification System for Design Professionals and the Building/Construction Industry	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	6, 10
American Institute of Architects Practice Guidelines	7. Improved Procedures and Practices	28
American Institute of Steel Construction Specification for Structural Steel Buildings	1. Increased Structural Integrity 3. New Methods for Fire Resistant Design of Structures	1, 3, 8, 9, 11
American Society of Civil Engineers, ASCE 7 – Minimum Design Loads for Buildings and Other Structures	1. Increased Structural Integrity 3. New Methods for Fire Resistant Design of Structures	1, 2, 3, 8, 9
American Society of Civil Engineers, ASCE 29 – Standard Calculation Methods for Structural Fire Protection	1. Increased Structural Integrity 3. New Methods for Fire Resistant Design of Structures	1, 8, 9
American Society of Mechanical Engineers, ASME A 17 – Elevators and Escalators, and A 17.1 – Safety Code for Elevators and Escalators	5. Improved Building Evacuation 6. Improved Emergency Response	17, 20, 21
American Society of Mechanical Engineers, ASME A 17.3 – Safety Code for Existing Elevators and Escalators	7. Improved Procedures and Practices	26
Association of the Wall and Ceiling Industry AWCI 12 – Design Selection Utilizing Sprayed Fire-Resistive Materials AWCI 12-A – Standard Practice for the Testing and Inspection of Field Applied Fire-Resistive Materials AWCI 12-B – Standard Practice for the Testing and Inspection of Field Applied Intumescent Fire-Resistive Materials	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	6, 10
ASTM International Committee E 06, Performance of Buildings; Subcommittee E 06.77, High-Rise Building External Evacuation Devices	5. Improved Building Evacuation	20
ASTM International, ASTM E 119 – Standard Test Methods for Fire Tests of Building Construction and Materials	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 11
Department of Homeland Security, National Incident Management System (NIMS)	6. Improved Emergency Response	23, 24

Affected Standard	Group Number	Recommendation
Department of Homeland Security, National Response Plan (NRP)	6. Improved Emergency Response	23, 24
Department of Homeland Security, SAFECOM	6. Improved Emergency Response	22, 23, 24
Federal Communications Commission, Emergency Responder Radio Communications Regulations	6. Improved Emergency Response	22, 23, 24
International Code Commission/American National Standards Institute, ICC/ANSI A117.1 – Accessible and Usable Buildings and Facilities	5. Improved Building Evacuation 6. Improved Emergency Response	16, 20, 21
International Organization for Standardization, ISO 834 – Fire Resistance Tests	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 11
National Fire Protection Association, NFPA 1 – Fire Prevention Code	4. Enhanced Active Fire Protection 7. Improved Procedures and Practices	12, 13, 14, 15, 26
National Fire Protection Association, NFPA 13 – Installation of Sprinkler Systems	4. Enhanced Active Fire Protection	12
National Fire Protection Association, NFPA 14 – Installation of Standpipe and Hose Systems	4. Enhanced Active Fire Protection	12
National Fire Protection Association, NFPA 20 – Installation of Stationary Pumps for Fire Protection	4. Enhanced Active Fire Protection	12
National Fire Protection Association, NFPA 70 – National Electrical Code	6. Improved Emergency Response	21, 22
National Fire Protection Association, NFPA 72 – National Fire Alarm Code	4. Enhanced Active Fire Protection	12, 13, 14, 15
National Fire Protection Association, NFPA 90A – Standard for Installation of Air-Conditioning and Ventilating Systems	4. Enhanced Active Fire Protection	12
National Fire Protection Association, NFPA 101 – Life Safety Code	4. Enhanced Active Fire Protection 5. Improved Building Evacuation 7. Improved Procedures and Practices	12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 26
National Fire Protection Association, NFPA 251 – Standard Methods of Tests of Fire Endurance of Building Construction and Materials	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 11
National Fire Protection Association, NFPA 297 – Guide on Principles and Practices for Communications Systems	6. Improved Emergency Response	22
National Fire Protection Association, NFPA 1221 – Standard for the Installation, Maintenance, and Use of Emergency Service Communications Systems	6. Improved Emergency Response	21, 22, 23, 24

Affected Standard	Group Number	Recommendation
National Fire Protection Association, NFPA 1500 – Standard on Fire Department Occupational Safety and Health	6. Improved Emergency Response	21, 23, 24
National Fire Protection Association, NFPA 1561 – Standard on Emergency Services Incident Management System	6. Improved Emergency Response	21, 23, 24
National Fire Protection Association, NFPA 1620 – Recommended Practice for Pre-Incident Planning	6. Improved Emergency Response	21, 23, 24
National Fire Protection Association, NFPA 1710 – Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments	6. Improved Emergency Response	21, 23, 24
Underwriters Laboratories, UL 263 – Fire Tests of Building Construction and Materials	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 9, 11

Table 9–2b. Model Codes Affected by the Recommendations.

Affected Model Code	Group	Recommendation
International Building Code	1. Increased Structural Integrity 2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures 4. Improved Active Fire Protection 5. Improved Building Evacuation 6. Improved Emergency Response 7. Improved Procedures and Practices 8. Education and Training	1–24, 26–29
International Existing Building Code	7. Improved Procedures and Practices	26
International Fire Code	7. Improved Procedures and Practices	26
National Fire Protection Association, NFPA 5000 – Building Construction and Safety Code	1. Increased Structural Integrity 2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures 4. Improved Active Fire Protection 5. Improved Building Evacuation 6. Improved Emergency Response 7. Improved Procedures and Practices 8. Education and Training	1–24, 26–29

Table 9–2c. Organizations Affected by the Recommendations.

Affected Organization	Group	Recommendation
American Concrete Institute	1. Increased Structural Integrity 2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures 8. Education and Training	1, 3, 6, 8, 9, 11, 29, 30
American Institute of Architects	7. Improved Procedures and Practices 8. Education and Training	28, 29, 30
American Institute of Steel Construction	3. New Methods for Fire Resistant Design of Structures 8. Education and Training	1, 3, 8, 9, 29, 30
American National Standards Institute	5. Improved Building Evacuation 6. Improved Emergency Response	16, 20, 21
American Society of Civil Engineers	1. Increased Structural Integrity 3. New Methods for Fire Resistant Design of Structures 7. Improved Procedures and Practices 8. Education and Training	1, 2, 3, 8, 9, 26, 29, 30
American Society of Mechanical Engineers	2. Enhanced Fire Endurance of Structures 5. Improved Building Evacuation 6. Improved Emergency Response 8. Education and Training	5, 17, 20, 21, 29, 30
Association of the Wall and Ceiling Industry	2. Enhanced Fire Endurance of Structures	6
ASTM International	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures 5. Improved Building Evacuation	6, 9, 10, 11, 20
Building Owners & Managers Association	5. Improved Building Evacuation	16
Council on Tall Buildings and Urban Habitat	5. Improved Building Evacuation	16
Department of Homeland Security	6. Improved Building Evacuation	22, 23, 24
Federal Communications Commission	6. Improved Emergency Response	22, 23, 24
International Code Council	1. Increased Structural Integrity 2. Enhanced Fire Endurance of Structures 5. Improved Building Evacuation 8. Education and Training	1, 4, 16, 30
International Organization for Standardization	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 9, 11
National Conference of States on Building Codes & Standards, Inc.	5. Improved Building Evacuation	16

Affected Organization	Group	Recommendation
National Fire Protection Association	1. Increased Structural Integrity 2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures 4. Enhance Active Fire Protection 5. Improved Building Evacuation 6. Improved Emergency Response 7. Improved Procedures and Practices 8. Education and Training	1, 4, 5, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 30
National Institute of Building Sciences	5. Improved Building Evacuation	16
Society of Fire Protection Engineers	3. New Methods for Fire Resistant Design of Structures 8. Education and Training	8, 9, 29, 30
State licensing boards	8. Education and Training	29
Underwriters Laboratories	2. Enhanced Fire Endurance of Structures 3. New Methods for Fire Resistant Design of Structures	5, 11

Appendix A
NATIONAL CONSTRUCTION SAFETY TEAM ACT

Public Law 107–231
107th Congress

An Act

To provide for the establishment of investigative teams to assess building performance and emergency response and evacuation procedures in the wake of any building failure that has resulted in substantial loss of life or that posed significant potential of substantial loss of life.

Oct. 1, 2002
[H.R. 4687]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

National Construction Safety Team Act. 15 USC 7301 note.

SECTION 1. SHORT TITLE.

This Act may be cited as the "National Construction Safety Team Act".

SEC. 2. NATIONAL CONSTRUCTION SAFETY TEAMS.

15 USC 7301.

(a) ESTABLISHMENT.—The Director of the National Institute of Standards and Technology (in this Act referred to as the "Director") is authorized to establish National Construction Safety Teams (in this Act referred to as a "Team") for deployment after events causing the failure of a building or buildings that has resulted in substantial loss of life or that posed significant potential for substantial loss of life. To the maximum extent practicable, the Director shall establish and deploy a Team within 48 hours after such an event. The Director shall promptly publish in the Federal Register notice of the establishment of each Team.

Federal Register, publication.

(b) PURPOSE OF INVESTIGATION; DUTIES.—

(1) PURPOSE.—The purpose of investigations by Teams is to improve the safety and structural integrity of buildings in the United States.

(2) DUTIES.—A Team shall—

(A) establish the likely technical cause or causes of the building failure;

(B) evaluate the technical aspects of evacuation and emergency response procedures;

(C) recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to subparagraphs (A) and (B); and

(D) recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve evacuation and emergency response procedures, based on the findings of the investigation.

(c) PROCEDURES.—

(1) DEVELOPMENT.—Not later than 3 months after the date of the enactment of this Act, the Director, in consultation with the United States Fire Administration and other appropriate Federal agencies, shall develop procedures for the establishment and deployment of Teams. The Director shall

Deadline.

update such procedures as appropriate. Such procedures shall include provisions—

(A) regarding conflicts of interest related to service on the Team;

(B) defining the circumstances under which the Director will establish and deploy a Team;

(C) prescribing the appropriate size of Teams;

(D) guiding the disclosure of information under section 8;

(E) guiding the conduct of investigations under this Act, including procedures for providing written notice of inspection authority under section 4(a) and for ensuring compliance with any other applicable law;

(F) identifying and prescribing appropriate conditions for the provision by the Director of additional resources and services Teams may need;

(G) to ensure that investigations under this Act do not impede and are coordinated with any search and rescue efforts being undertaken at the site of the building failure;

(H) for regular briefings of the public on the status of the investigative proceedings and findings;

(I) guiding the Teams in moving and preserving evidence as described in section 4 (a)(4), (b)(2), and (d)(4);

(J) providing for coordination with Federal, State, and local entities that may sponsor research or investigations of building failures, including research conducted under the Earthquake Hazards Reduction Act of 1977; and

(K) regarding such other issues as the Director considers appropriate.

Federal Register, publication.

(2) PUBLICATION.—The Director shall publish promptly in the Federal Register final procedures, and subsequent updates thereof, developed under paragraph (1).

15 USC 7302.

SEC. 3. COMPOSITION OF TEAMS.

Each Team shall be composed of individuals selected by the Director and led by an individual designated by the Director. Team members shall include at least 1 employee of the National Institute of Standards and Technology and shall include other experts who are not employees of the National Institute of Standards and Technology, who may include private sector experts, university experts, representatives of professional organizations with appropriate expertise, and appropriate Federal, State, or local officials. Team members who are not Federal employees shall be considered Federal Government contractors.

15 USC 7303.

SEC. 4. AUTHORITIES.

(a) ENTRY AND INSPECTION.—In investigating a building failure under this Act, members of a Team, and any other person authorized by the Director to support a Team, on display of appropriate credentials provided by the Director and written notice of inspection authority, may—

(1) enter property where a building failure being investigated has occurred, or where building components, materials, and artifacts with respect to the building failure are located, and take action necessary, appropriate, and reasonable in light of the nature of the property to be inspected to carry out the duties of the Team under section 2(b)(2) (A) and (B);

(2) during reasonable hours, inspect any record (including any design, construction, or maintenance record), process, or facility related to the investigation;

(3) inspect and test any building components, materials, and artifacts related to the building failure; and

(4) move such records, components, materials, and artifacts as provided by the procedures developed under section 2(c)(1).

(b) AVOIDING UNNECESSARY INTERFERENCE AND PRESERVING EVIDENCE.—An inspection, test, or other action taken by a Team under this section shall be conducted in a way that—

(1) does not interfere unnecessarily with services provided by the owner or operator of the building components, materials, or artifacts, property, records, process, or facility; and

(2) to the maximum extent feasible, preserves evidence related to the building failure, consistent with the ongoing needs of the investigation.

(c) COORDINATION.—

(1) WITH SEARCH AND RESCUE EFFORTS.—A Team shall not impede, and shall coordinate its investigation with, any search and rescue efforts being undertaken at the site of the building failure.

(2) WITH OTHER RESEARCH.—A Team shall coordinate its investigation, to the extent practicable, with qualified researchers who are conducting engineering or scientific (including social science) research relating to the building failure.

(3) MEMORANDA OF UNDERSTANDING.—The National Institute of Standards and Technology shall enter into a memorandum of understanding with each Federal agency that may conduct or sponsor a related investigation, providing for coordination of investigations.

(4) WITH STATE AND LOCAL AUTHORITIES.—A Team shall cooperate with State and local authorities carrying out any activities related to a Team's investigation.

(d) INTERAGENCY PRIORITIES.—

(1) IN GENERAL.—Except as provided in paragraph (2) or (3), a Team investigation shall have priority over any other investigation of any other Federal agency.

(2) NATIONAL TRANSPORTATION SAFETY BOARD.—If the National Transportation Safety Board is conducting an investigation related to an investigation of a Team, the National Transportation Safety Board investigation shall have priority over the Team investigation. Such priority shall not otherwise affect the authority of the Team to continue its investigation under this Act.

(3) CRIMINAL ACTS.—If the Attorney General, in consultation with the Director, determines, and notifies the Director, that circumstances reasonably indicate that the building failure being investigated by a Team may have been caused by a criminal act, the Team shall relinquish investigative priority to the appropriate law enforcement agency. The relinquishment of investigative priority by the Team shall not otherwise affect the authority of the Team to continue its investigation under this Act.

(4) PRESERVATION OF EVIDENCE.—If a Federal law enforcement agency suspects and notifies the Director that a building failure being investigated by a Team under this Act may have

been caused by a criminal act, the Team, in consultation with the Federal law enforcement agency, shall take necessary actions to ensure that evidence of the criminal act is preserved.

15 USC 7304.

SEC. 5. BRIEFINGS, HEARINGS, WITNESSES, AND SUBPOENAS.

(a) GENERAL AUTHORITY.—The Director or his designee, on behalf of a Team, may conduct hearings, administer oaths, and require, by subpoena (pursuant to subsection (e)) and otherwise, necessary witnesses and evidence as necessary to carry out this Act.

(b) BRIEFINGS.—The Director or his designee (who may be the leader or a member of a Team), on behalf of a Team, shall hold regular public briefings on the status of investigative proceedings and findings, including a final briefing after the report required by section 8 is issued.

(c) PUBLIC HEARINGS.—During the course of an investigation by a Team, the National Institute of Standards and Technology may, if the Director considers it to be in the public interest, hold a public hearing for the purposes of—

(1) gathering testimony from witnesses; and

(2) informing the public on the progress of the investigation.

(d) PRODUCTION OF WITNESSES.—A witness or evidence in an investigation under this Act may be summoned or required to be produced from any place in the United States. A witness summoned under this subsection is entitled to the same fee and mileage the witness would have been paid in a court of the United States.

(e) ISSUANCE OF SUBPOENAS.—A subpoena shall be issued only under the signature of the Director but may be served by any person designated by the Director.

(f) FAILURE TO OBEY SUBPOENA.—If a person disobeys a subpoena issued by the Director under this Act, the Attorney General, acting on behalf of the Director, may bring a civil action in a district court of the United States to enforce the subpoena. An action under this subsection may be brought in the judicial district in which the person against whom the action is brought resides, is found, or does business. The court may punish a failure to obey an order of the court to comply with the subpoena as a contempt of court.

15 USC 7305.

SEC. 6. ADDITIONAL POWERS.

In order to support Teams in carrying out this Act, the Director may—

(1) procure the temporary or intermittent services of experts or consultants under section 3109 of title 5, United States Code;

(2) request the use, when appropriate, of available services, equipment, personnel, and facilities of a department, agency, or instrumentality of the United States Government on a reimbursable or other basis;

(3) confer with employees and request the use of services, records, and facilities of State and local governmental authorities;

(4) accept voluntary and uncompensated services;

(5) accept and use gifts of money and other property, to the extent provided in advance in appropriations Acts;

(6) make contracts with nonprofit entities to carry out studies related to purpose, functions, and authorities of the Teams; and

(7) provide nongovernmental members of the Team reasonable compensation for time spent carrying out activities under this Act.

SEC. 7. DISCLOSURE OF INFORMATION. 15 USC 7306.

(a) GENERAL RULE.—Except as otherwise provided in this section, a copy of a record, information, or investigation submitted or received by a Team shall be made available to the public on request and at reasonable cost. Records.

(b) EXCEPTIONS.—Subsection (a) does not require the release of—

(1) information described by section 552(b) of title 5, United States Code, or protected from disclosure by any other law of the United States; or

(2) information described in subsection (a) by the National Institute of Standards and Technology or by a Team until the report required by section 8 is issued.

(c) PROTECTION OF VOLUNTARY SUBMISSION OF INFORMATION.—Notwithstanding any other provision of law, a Team, the National Institute of Standards and Technology, and any agency receiving information from a Team or the National Institute of Standards and Technology, shall not disclose voluntarily provided safety-related information if that information is not directly related to the building failure being investigated and the Director finds that the disclosure of the information would inhibit the voluntary provision of that type of information.

(d) PUBLIC SAFETY INFORMATION.—A Team and the National Institute of Standards and Technology shall not publicly release any information it receives in the course of an investigation under this Act if the Director finds that the disclosure of that information might jeopardize public safety.

SEC. 8. NATIONAL CONSTRUCTION SAFETY TEAM REPORT. 15 USC 7307.

Not later than 90 days after completing an investigation, a Team shall issue a public report which includes— Deadline.

(1) an analysis of the likely technical cause or causes of the building failure investigated;

(2) any technical recommendations for changes to or the establishment of evacuation and emergency response procedures;

(3) any recommended specific improvements to building standards, codes, and practices; and

(4) recommendations for research and other appropriate actions needed to help prevent future building failures.

SEC. 9. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY ACTIONS. 15 USC 7308.

After the issuance of a public report under section 8, the National Institute of Standards and Technology shall comprehensively review the report and, working with the United States Fire Administration and other appropriate Federal and non-Federal agencies and organizations—

(1) conduct, or enable or encourage the conducting of, appropriate research recommended by the Team; and

(2) promote (consistent with existing procedures for the establishment of building standards, codes, and practices) the

appropriate adoption by the Federal Government, and encourage the appropriate adoption by other agencies and organizations, of the recommendations of the Team with respect to—

(A) technical aspects of evacuation and emergency response procedures;

(B) specific improvements to building standards, codes, and practices; and

(C) other actions needed to help prevent future building failures.

15 USC 7309.

SEC. 10. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY ANNUAL REPORT.

Deadline.

Not later than February 15 of each year, the Director shall transmit to the Committee on Science of the House of Representatives and to the Committee on Commerce, Science, and Transportation of the Senate a report that includes—

(1) a summary of the investigations conducted by Teams during the prior fiscal year;

(2) a summary of recommendations made by the Teams in reports issued under section 8 during the prior fiscal year and a description of the extent to which those recommendations have been implemented; and

(3) a description of the actions taken to improve building safety and structural integrity by the National Institute of Standards and Technology during the prior fiscal year in response to reports issued under section 8.

15 USC 7310.

SEC. 11. ADVISORY COMMITTEE.

(a) ESTABLISHMENT AND FUNCTIONS.—The Director, in consultation with the United States Fire Administration and other appropriate Federal agencies, shall establish an advisory committee to advise the Director on carrying out this Act and to review the procedures developed under section 2(c)(1) and the reports issued under section 8.

Deadline.

(b) ANNUAL REPORT.—On January 1 of each year, the advisory committee shall transmit to the Committee on Science of the House of Representatives and to the Committee on Commerce, Science, and Transportation of the Senate a report that includes—

(1) an evaluation of Team activities, along with recommendations to improve the operation and effectiveness of Teams; and

(2) an assessment of the implementation of the recommendations of Teams and of the advisory committee.

(c) DURATION OF ADVISORY COMMITTEE.—Section 14 of the Federal Advisory Committee Act shall not apply to the advisory committee established under this section.

15 USC 7311.

SEC. 12. ADDITIONAL APPLICABILITY.

The authorities and restrictions applicable under this Act to the Director and to Teams shall apply to the activities of the National Institute of Standards and Technology in response to the attacks of September 11, 2001.

SEC. 13. AMENDMENT.

Section 7 of the National Bureau of Standards Authorization Act for Fiscal Year 1986 (15 U.S.C. 281a) is amended by inserting ", or from an investigation under the National Construction Safety Team Act," after "from such investigation".

SEC. 14. CONSTRUCTION. 15 USC 7312.

Nothing in this Act shall be construed to confer any authority on the National Institute of Standards and Technology to require the adoption of building standards, codes, or practices.

SEC. 15. AUTHORIZATION OF APPROPRIATIONS. 15 USC 7313.

The National Institute of Standards and Technology is authorized to use funds otherwise authorized by law to carry out this Act.

Approved October 1, 2002.

LEGISLATIVE HISTORY—H.R. 4687:

HOUSE REPORTS: No. 107–530 (Comm. on Science).
CONGRESSIONAL RECORD, Vol. 148 (2002):
July 12, considered and passed House.
Sept. 9, considered and passed Senate, amended.
Sept. 17, House concurred in Senate amendment.

This page intentionally left blank.

Appendix B
WORLD TRADE CENTER INVESTIGATION PUBLICATIONS

This report, NIST NCSTAR 1, covers the WTC towers, with a separate report on the 47-story WTC 7. Supporting documentation of the techniques and technologies used in the investigation are in a set of companion reports that provide more details of the Investigation findings and the means by which these technical results were achieved. The titles of the full set of Investigation publications are:

NIST (National Institute of Standards and Technology). 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Final Report on the Collapse of the World Trade Center Towers.* NIST NCSTAR 1. Gaithersburg, MD, September.

NIST (National Institute of Standards and Technology). 2006. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Final Report on the Collapse of World Trade Center 7.* NIST NCSTAR 1A. Gaithersburg, MD.

Lew, H. S., R. W. Bukowski, and N. J. Carino. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Design, Construction, and Maintenance of Structural and Life Safety Systems.* NIST NCSTAR 1-1. National Institute of Standards and Technology. Gaithersburg, MD, September.

Fanella, D. A., A. T. Derecho, and S. K. Ghosh. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Design and Construction of Structural Systems.* NIST NCSTAR 1-1A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Ghosh, S. K., and X. Liang. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Comparison of Building Code Structural Requirements.* NIST NCSTAR 1-1B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Fanella, D. A., A. T. Derecho, and S. K. Ghosh. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Maintenance and Modifications to Structural Systems.* NIST NCSTAR 1-1C. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., and D. A. Johnson. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Protection and Life Safety Provisions Applied to the Design and Construction of World Trade Center 1, 2, and 7 and Post-Construction Provisions Applied after Occupancy.* NIST NCSTAR 1-1D. National Institute of Standards and Technology. Gaithersburg, MD, September.

Razza, J. C., and R. A. Grill. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Comparison of Codes, Standards, and Practices in Use at the Time of the Design and Construction of World Trade Center 1, 2, and 7.* NIST NCSTAR 1-1E. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., D. A. Johnson, and D. A. Fanella. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Comparison of the 1968 and Current (2003) New York City Building Code Provisions.* NIST NCSTAR 1-1F. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., and D. A. Johnson. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Amendments to the Fire Protection and Life Safety Provisions of the New York City Building Code by Local Laws Adopted While World Trade Center 1, 2, and 7 Were in Use.* NIST NCSTAR 1-1G. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., and D. A. Johnson. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Post-Construction Modifications to Fire Protection and Life Safety Systems of World Trade Center 1 and 2.* NIST NCSTAR 1-1H. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., D. A. Johnson, and D. A. Fanella. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Post-Construction Modifications to Fire Protection, Life Safety, and Structural Systems of World Trade Center 7.* NIST NCSTAR 1-1I. National Institute of Standards and Technology. Gaithersburg, MD, September.

Grill, R. A., and D. A. Johnson. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Design, Installation, and Operation of Fuel System for Emergency Power in World Trade Center 7.* NIST NCSTAR 1-1J. National Institute of Standards and Technology. Gaithersburg, MD, September.

Sadek, F. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Baseline Structural Performance and Aircraft Impact Damage Analysis of the World Trade Center Towers.* NIST NCSTAR 1-2. National Institute of Standards and Technology. Gaithersburg, MD, September.

Faschan, W. J., and R. B. Garlock. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Reference Structural Models and Baseline Performance Analysis of the World Trade Center Towers.* NIST NCSTAR 1-2A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Kirkpatrick, S. W., R. T. Bocchieri, F. Sadek, R. A. MacNeill, S. Holmes, B. D. Peterson, R. W. Cilke, C. Navarro. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Analysis of Aircraft Impacts into the World Trade Center Towers,* NIST NCSTAR 1-2B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Gayle, F. W., R. J. Fields, W. E. Luecke, S. W. Banovic, T. Foecke, C. N. McCowan, T. A. Siewert, and J. D. McColskey. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Mechanical and Metallurgical Analysis of Structural Steel.* NIST NCSTAR 1-3. National Institute of Standards and Technology. Gaithersburg, MD, September.

Luecke, W. E., T. A. Siewert, and F. W. Gayle. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Contemporaneous Structural Steel Specifications.* NIST Special Publication 1-3A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Banovic, S. W. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Steel Inventory and Identification.* NIST NCSTAR 1-3B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Banovic, S. W., and T. Foecke. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Damage and Failure Modes of Structural Steel Components.* NIST NCSTAR 1-3C. National Institute of Standards and Technology. Gaithersburg, MD, September.

Luecke, W. E., J. D. McColskey, C. N. McCowan, S. W. Banovic, R. J. Fields, T. Foecke, T. A. Siewert, and F. W. Gayle. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Mechanical Properties of Structural Steels.* NIST NCSTAR 1-3D. National Institute of Standards and Technology. Gaithersburg, MD, September.

Banovic, S. W., C. N. McCowan, and W. E. Luecke. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Physical Properties of Structural Steels.* NIST NCSTAR 1-3E. National Institute of Standards and Technology. Gaithersburg, MD, September.

Evans, D. D., R. D. Peacock, E. D. Kuligowski, W. S. Dols, and W. L. Grosshandler. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Active Fire Protection Systems.* NIST NCSTAR 1-4. National Institute of Standards and Technology. Gaithersburg, MD, September.

Kuligowski, E. D., D. D. Evans, and R. D. Peacock. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Post-Construction Fires Prior to September 11, 2001.* NIST NCSTAR 1-4A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Hopkins, M., J. Schoenrock, and E. Budnick. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Suppression Systems.* NIST NCSTAR 1-4B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Keough, R. J., and R. A. Grill. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Alarm Systems.* NIST NCSTAR 1-4C. National Institute of Standards and Technology. Gaithersburg, MD, September.

Ferreira, M. J., and S. M. Strege. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Smoke Management Systems.* NIST NCSTAR 1-4D. National Institute of Standards and Technology. Gaithersburg, MD, September.

Gann, R. G., A. Hamins, K. B. McGrattan, G. W. Mulholland, H. E. Nelson, T. J. Ohlemiller, W. M. Pitts, and K. R. Prasad. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Reconstruction of the Fires in the World Trade Center Towers.* NIST NCSTAR 1-5. National Institute of Standards and Technology. Gaithersburg, MD, September.

Pitts, W. M., K. M. Butler, and V. Junker. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Visual Evidence, Damage Estimates, and Timeline Analysis.* NIST NCSTAR 1-5A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Hamins, A., A. Maranghides, K. B. McGrattan, E. Johnsson, T. J. Ohlemiller, M. Donnelly, J. Yang, G. Mulholland, K. R. Prasad, S. Kukuck, R. Anleitner and T. McAllister. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Experiments and Modeling of Structural Steel Elements Exposed to Fire.* NIST NCSTAR 1-5B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Ohlemiller, T. J., G. W. Mulholland, A. Maranghides, J. J. Filliben, and R. G. Gann. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Tests of Single Office Workstations.* NIST NCSTAR 1-5C. National Institute of Standards and Technology. Gaithersburg, MD, September.

Gann, R. G., M. A. Riley, J. M. Repp, A. S. Whittaker, A. M. Reinhorn, and P. A. Hough. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Reaction of Ceiling Tile Systems to Shocks.* NIST NCSTAR 1-5D. National Institute of Standards and Technology. Gaithersburg, MD, September.

Hamins, A., A. Maranghides, K. B. McGrattan, T. J. Ohlemiller, and R. Anleitner. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Experiments and Modeling of Multiple Workstations Burning in a Compartment.* NIST NCSTAR 1-5E. National Institute of Standards and Technology. Gaithersburg, MD, September.

McGrattan, K. B., C. Bouldin, and G. Forney. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Computer Simulation of the Fires in the World Trade Center Towers.* NIST NCSTAR 1-5F. National Institute of Standards and Technology. Gaithersburg, MD, September.

Prasad, K. R., and H. R. Baum. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Structure Interface and Thermal Response of the World Trade Center Towers.* NIST NCSTAR 1-5G. National Institute of Standards and Technology. Gaithersburg, MD, September.

Gross, J. L., and T. McAllister. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Structural Fire Response and Probable Collapse Sequence of the World Trade Center Towers.* NIST NCSTAR 1-6. National Institute of Standards and Technology. Gaithersburg, MD, September.

Carino, N. J., M. A. Starnes, J. L. Gross, J. C. Yang, S. Kukuck, K. R. Prasad, and R. W. Bukowski. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Passive Fire Protection.* NIST NCSTAR 1-6A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Gross, J., F. Hervey, M. Izydorek, J. Mammoser, and J. Treadway. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Fire Resistance Tests of Floor Truss Systems.* NIST NCSTAR 1-6B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Zarghamee, M. S., S. Bolourchi, D. W. Eggers, Ö. O. Erbay, F. W. Kan, Y. Kitane, A. A. Liepins, M. Mudlock, W. I. Naguib, R. P. Ojdrovic, A. T. Sarawit, P. R Barrett, J. L. Gross, and T. P. McAllister. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Component, Connection, and Subsystem Structural Analysis.* NIST NCSTAR 1-6C. National Institute of Standards and Technology. Gaithersburg, MD, September.

Zarghamee, M. S., Y. Kitane, Ö. O. Erbay, T. P. McAllister, and J. L. Gross. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Global Structural Analysis of the Response of the World Trade Center Towers to Impact Damage and Fire.* NIST NCSTAR 1-6D. National Institute of Standards and Technology. Gaithersburg, MD, September.

McAllister, T., R. W. Bukowski, R. G. Gann, J. L. Gross, K. B. McGrattan, H. E. Nelson, L. Phan, W. M. Pitts, K. R. Prasad, F. Sadek. 2006. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Structural Fire Response and Probable Collapse Sequence of World Trade Center 7.* (Provisional). NIST NCSTAR 1-6E. National Institute of Standards and Technology. Gaithersburg, MD.

Gilsanz, R., V. Arbitrio, C. Anders, D. Chlebus, K. Ezzeldin, W. Guo, P. Moloney, A. Montalva, J. Oh, K. Rubenacker. 2006. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Structural Analysis of the Response of World Trade Center 7 to Debris Damage and Fire.* (Provisional). NIST NCSTAR 1-6F. National Institute of Standards and Technology. Gaithersburg, MD.

Kim, W. 2006. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Analysis of September 11, 2001, Seismogram Data.* (Provisional). NIST NCSTAR 1-6G. National Institute of Standards and Technology. Gaithersburg, MD.

Nelson, K. 2006. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: The Con Ed Substation in World Trade Center 7.* (Provisional). NIST NCSTAR 1-6H. National Institute of Standards and Technology. Gaithersburg, MD.

Averill, J. D., D. S. Mileti, R. D. Peacock, E. D. Kuligowski, N. Groner, G. Proulx, P. A. Reneke, and H. E. Nelson. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Occupant Behavior, Egress, and Emergency Communication.* NIST NCSTAR 1-7. National Institute of Standards and Technology. Gaithersburg, MD, September.

Fahy, R., and G. Proulx. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Analysis of Published Accounts of the World Trade Center Evacuation.* NIST NCSTAR 1-7A. National Institute of Standards and Technology. Gaithersburg, MD, September.

Zmud, J. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: Technical Documentation for Survey Administration.* NIST NCSTAR 1-7B. National Institute of Standards and Technology. Gaithersburg, MD, September.

Lawson, J. R., and R. L. Vettori. 2005. *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: The Emergency Response Operations.* NIST NCSTAR 1-8. National Institute of Standards and Technology. Gaithersburg, MD, September.

Appendix C
SUBJECT INDEX OF SUPPORTING INVESTIGATION REPORTS

The purpose of this index is to direct readers of NIST NCSTAR 1 to the supporting Investigation reports in which more detailed descriptions of the topics covered in this report can be found. The citations refer to the NIST NCSTAR report numbers; complete citations are in Appendix B to this report. For a subject referenced in a report with a number and a letter (e.g., 1-5A), a summary description of the topic can be found in the report with the number alone (e.g., 1-5). In most of the citations, the pertinent chapter or section numbers in the report appears in parentheses. The absence of these parenthetical locations indicates that much of the report is on that topic.

This page intentionally left blank.